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An excavation technique for sampling undisturbed soil columns for hydrologic characteristics determination

T.L. Chow and B.A. Roberts

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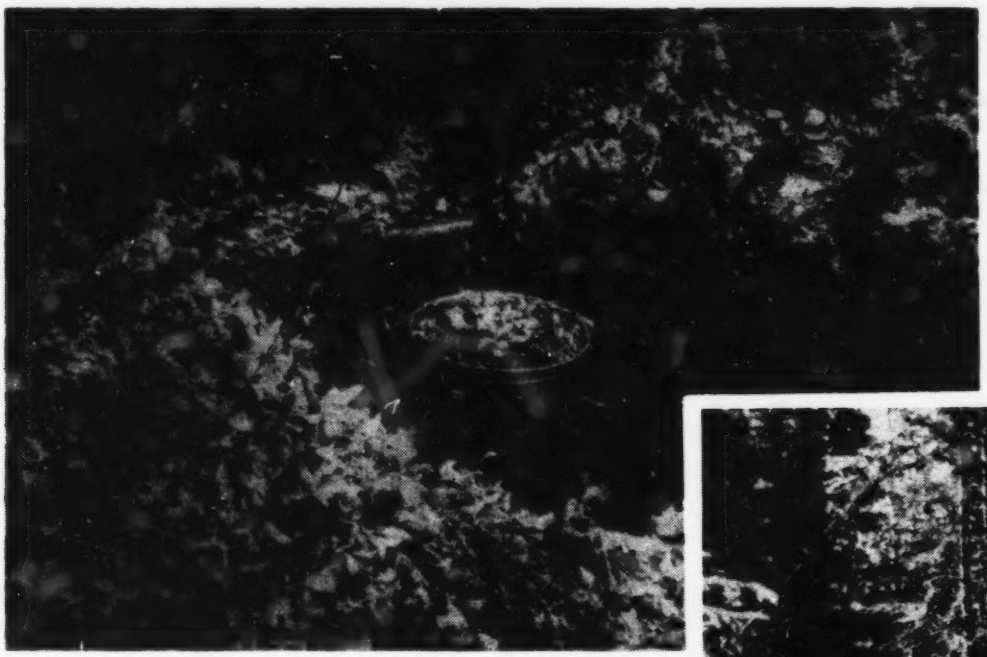

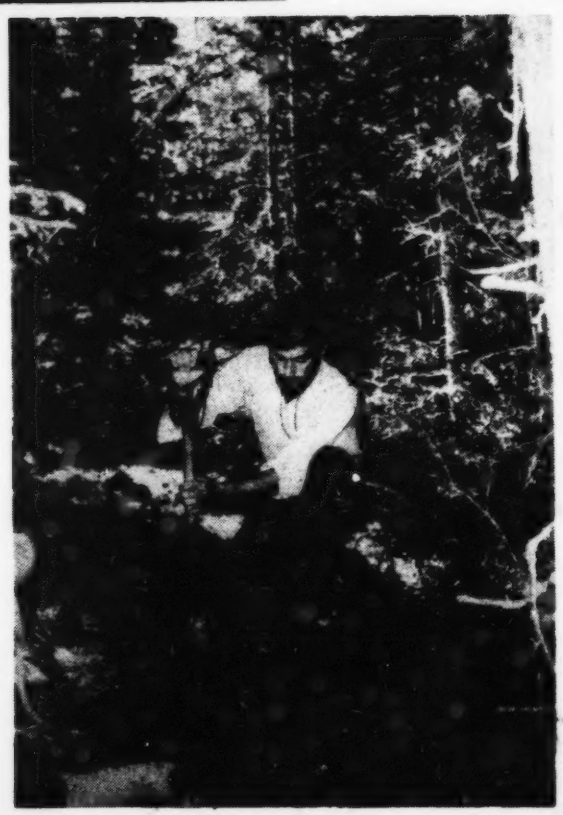

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ABSTRACT

An excavation technique employing basic hand tools has been developed to sample large undisturbed soil columns for laboratory determination of water retention and flow characteristics. This method is especially designed for forest soils which contain an abundance of roots and gravels. By this method a more representative sample is possible because of larger volume and less disturbance as compared to a conventional soil core. Moreover, free water flow along the soil-container interface is eliminated, thus overcoming a major difficulty encountered in laboratory determination of saturated hydraulic conductivity. Such undisturbed soils may also be used for bulk density measurements, micromorphological studies and other purposes.

RÉSUMÉ

Une technique d'excavation faisant appel à des outils de base a été mise a point pour l'obtention d'importantes colonnes de sol non perturbé en vue de la détermination au laboratoire des caractéristiques de rétention et d'écoulement de l'eau. Cette méthode est conçue spécialement pour les sols forestiers dans lesquels les racines et les graviers abondent. Elle permet d'obtenir un échantillon plus représentatif, car le volume prélevé est plus grand, et la perturbation occasionnée, plus faible par rapport à la méthode classique de carottage. De plus, l'écoulement d'eau libre à l'interface sol-récipient étant éliminé, une difficulté majeure de la détermination en laboratoire de la conductivité hydraulique du sol saturé se trouve ainsi résolue. Les échantillons de sol non perturbé obtenus grâce à cetter nouvelle méthode peuvent également servir à d'autres fins telles que les déterminations de la densité apparente et les études micromorphologiques.

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AN EXCAVATION TECHNIQUE FOR SAMPLING UNDISTURBED SOIL COLUMNS FOR HYDROLOGIC CHARACTERISTICS DETERMINATION

by

T.L. Chow[1] and B.A. Roberts

INTRODUCTION

In soil physics research, relatively undisturbed soil columns which retain natural structure are often needed for laboratory determination of bulk density, pore size distribution and hydrologic characteristics. Soil coring machines or samplers for obtaining undisturbed soil cores in agricultural soils are available in a variety of designs to suit various purposes (e.g., Watson and Lees 1975; Robertson et al. 1974; Jamison et al. 1950). The applicability of these apparatus in forest soils is often limited by an abundance of roots and gravels. A freezing technique using liquid nitrogen to freeze a block of soil in situ before excavation is available to collect undisturbed samples from forest soils (Blevins et al. 1968). However, this method is not suitable for soil with moisture content higher than field capacity because excessive ice formation retards the penetration of liquid nitrogen and disturbs soil structure by increasing pore volume. Moreover, the nature of the collected sample is not suitable for determination of hydrologic characteristics. Mehuys and DeKimpe (1976) report another method of collecting undisturbed individual soil samples in which soil blocks of

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approximately 10 x 10 cm cross section and 12 to 15 cm in height from different horizons in a given profile. Soil blocks are trimmed to fit loosely inside galvanized steel containers or waxed milk cartons; the soil block is placed in the container and melted paraffin is then poured around it to retain the structure. Because of difficulties in collecting undisturbed blocks of soil from horizons containing an abundance of roots and gravels, this method also is suitable for forest soils.

This report describes an excavation technique for collecting large undisturbed soil columns which are suitable for determinations of moisture retention and flow characteristics, as well as bulk density measurements and micro-morphological studies. The technique minimizes the difficulties associated with roots and gravels when collecting undisturbed soil columns.

MATERIALS AND METHODS

A metal cylinder with an inner diameter of 28 cm and a height of 40 cm was used to retain the undisturbed sample. The cylinder was constructed by removing the top and bottom of an empty 22.7 ℓ (5 gal.) oil can. After cleaning the inside surface, the cylinder was ready for use.

Field Excavation

Within a selected sampling site, a column of soil approximately 60 cm in diameter was carefully isolated (using pick and

shovel) from the surrounding soil by a 60 cm deep trench. (A larger undisturbed column may be required for coarse textured soils.) All roots were cut with pruning shears to minimize disturbance. For soils with a thick LFH horizon, it is recommended that the organic layer be removed before sampling to maximize the depth of the collected mineral soil. After the trench was completed, the cylinder was placed on the centre of the undisturbed column. Soil outside the circumference of the cylinder was carefully removed in stages with spade or knife to a depth of 5 to 10 cm each time depending upon the consistency of the soil. All roots were carefully cut to fit the inner circumference of the cylinder and protruding stones were removed. Then, the cylinder was pushed down over the soil by applying evenly distributed force on the circumference of the cylinder. A piece of board laid on top of the cylinder was useful for this purpose. The stepwise lowering of the cylinder in small depth increments prevented collapse of the soil structure. Once the cylinder had been lowered to the desired depth, melted wax was gradually poured into the interface between the inner wall of the cylinder and the soil until the wax reached the bottom of the cylinder. The depth of wax penetration was detected by the temperature change of the cylinder. If the wax solidified before reaching the lower end of the cylinder, a propane torch was used to increase the temperature of the cylinder. Heat was applied evenly on the outside surface of the cylinder to minimize the possibility of wax penetrating the adjacent soil pores.

This could not be accomplished when using large diameter ABS sewer pipe which was also tested for this project. Care was also taken to prevent wax spills onto the soil surface which might cause a considerable reduction in the number of pores available for water flow. This is particularly important if the sample is to remain intact. Upon complete solidification of the wax - which was normally overnight - the relatively undisturbed soil column was ready for excavation. The prepared soil column before final excavation is shown in Fig. 1.

The column was excavated by separating it from the soil by carefully pushing a shovel under the sample and then tipping the column on its side. Any soil extending beyond the end of the cylinder was trimmed off and the bottom of the column was then supported with a styrofoam board. After wrapping the column in a heavy-weight polyethylene bag, it was ready for transportation to the laboratory. Vigorous vibration or rough handling of the column was avoided during transportation. In the laboratory, the column was stored in a cool room to minimize microbial activity prior to the initiation of measurements. Periodic addition of water was required to prevent cracking.

Laboratory Preparation of Soil Column

In the laboratory, saturated and unsaturated hydraulic conductivities of the collected column at various depth intervals were first measured, followed by determination of water retention properties and bulk densities. For determination of unsaturated hydraulic conductivity under steady state conditions (Childs and Collis-George 1950), a tension plate was required at the lower end of the column to eliminate the

Fig. 1. An undisturbed soil column prior to excavation.

the necessity of having a long column for obtaining a constant water content distribution (Wesseling and Wit 1968). Due to the weight and the fragility of the column, a special rack was developed to turn the column upside down for tension plate installation and to minimize disturbance of the soil structure. Fig. 2 shows an isometric view of the rack which consists of a height adjustable disc-shaped platform mounted on a raised rectangular stand. The diameter of the platform was slightly less than that of the soil column, and the long side of the stand wider than the diameter of the column. The disc was fastened to the stand by a threaded rod (3/8 - 24) through a threaded hole located at the center of the stand. The distance between the stand and the platform was adjusted by turning the rod at the underside of the stand. To install the tension plate, the rack was inverted onto the top of the cylinder. The disc was adjusted to fit tightly to the soil surface while the stand rested on the cylinder. The column and rack together were then turned over so that the cylinder rested on the stand and the soil was supported by the disc. After levelling the soil, the tension plate was attached to the base of the column with silicone sealant. A low flow impedence plate of unconsolidated or fritted glass bead (Chow 1977), should be used for soil with high organic matter content to reduce clogging. Tensiometers used in conjunction with water-filled manometers were then installed on the soil column at desired depths for measuring hydraulic gradients. During the measurements a multi-channel cassette pump was used to supply a constant flux of water to the surface of the soil column. An instantaneous profile method, similar to that of

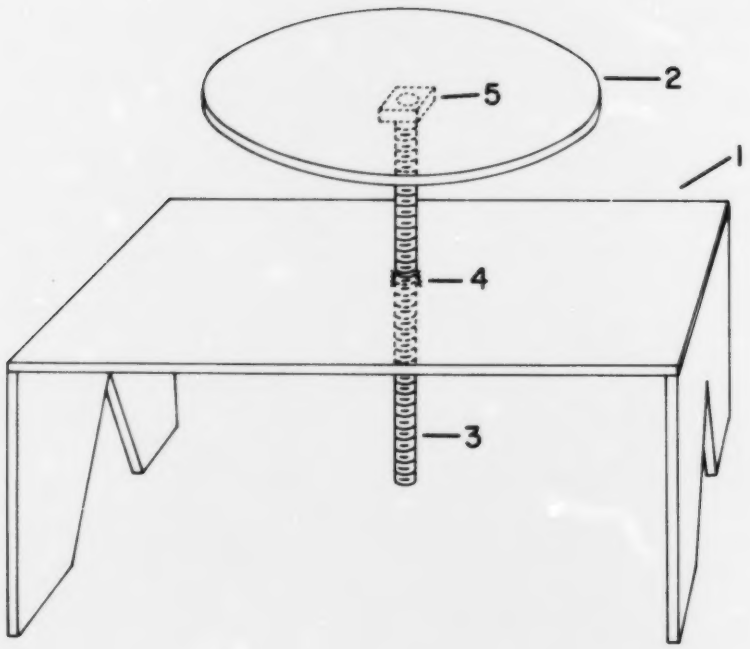

Fig. 2. Rack designed for installing a tension plate at the base of the soil column; (1) rectangular stand, 36 cm L x 21 cm W x 15 cm H (2) circular disk, 26 cm diameter; (3) 3/8 - 24 threaded metal rod, 20 cm; (4) 3/8 - 24 threaded hole; (5) 3/8 - 24 nut. Except the metal parts, the complete unit was constructed with 1.27 cm thick acrylic plastic.

Watson (1966), may also be used for determining unsaturated hydraulic conductivity of the column.

A similar arrangement was used to measure saturated hydraulic conductivity. The tension plate was replaced by a specially constructed plate with negligible flow impedence. This plate differed from a tension plate in that the porous material was replaced by a perforated acrylic plastic disk which in turn was covered with nylon screen and topped with cheese cloth to maximize the flow velocity. Thus, the error resulting from the hydraulic gradients measurement was substantially reduced.

Upon completing the hydraulic conductivities measurements, the metal cylinder was removed from the soil column and the soil was subdivided into different sections according to the locations of the tensiometers. Several undisturbed soil blocks from each section were then arbitrarily selected for the steady state equilibrium method of determining partial water retention characteristics at matric water potential higher than -0.15 bar (Haines 1930). A layer of unconsolidated glass bead was added to the top of the porous plate before placing the soil blocks. This increased the contact area between the soil surface and the plate. Porous plate extractors were used for similar determinations at lower water potential by using thin layers of undisturbed soil.

In addition to the primary objective of collecting relatively undisturbed soil columns, soil blocks similar to those used for partial water retention characteristic determination were also used for bulk

density measurement by the clod method (Blake 1965) and for the preparation of micro-monoliths.

RESULTS AND DISCUSSIONS

This method has been used to excavate more than 30 undisturbed soil columns for studying changes in soil hydrologic characteristics following forest harvesting and road construction. Most columns were collected from clearcut areas. Soils ranged from stony sandy loam to clay loam in the B horizons and compacted glacial till to alluvial sand in the C horizons. The forest floor, Ae and upper B horizons are characterized by the presence of many roots, gravels and decayed logs. At the time of sampling, the soils exhibited varying degrees of wetness including waterlogged conditions. No major difficulty was encountered during sampling and the time required to excavate a column ranged between two to three hours depending upon the type of soil and the root content.

The primary objective of obtaining relatively undisturbed soil columns is to determine their water retention and flow characteristics. The advantages of using such columns are twofold: first, samples are more representative because of the larger volume as compared with conventional soil cores (7.6 cm in diameter x 7.6 cm in height), and second, they eliminate free water flow along the soil-container interface which is a major difficulty encountered in most laboratory determinations of saturated hydraulic conductivity. Fig. 3 shows the wax-soil interface removed from a soil column upon completion of measurements. It indicates that a perfect penetration of the melted wax along

Fig. 3. Photograph of a wax-soil interface removed from a soil column upon completion of hydraulic conductivities measurements.

the heterogeneous-grained soil surface was obtained. This ensures the elimination of free water flow along the soil-container interface. Fig. 3 also shows that the permeation of wax into the soil pores was reduced to a minimum which simplifies the estimation of the effective cross sectional area of soil available for water flow in calculating the hydraulic conductivity.

An example of the saturated hydraulic conductivities of a soil column collected by this method is shown in Fig. 4. The soil is an orthic humo-ferric podzol developed on glacial till. The profile is characterized by the presence of many roots and gravels. Under this condition, it is normally very difficult to collect undisturbed soil cores by conventional methods. The results in Fig. 4 indicate that the saturated hydraulic conductivities increased slightly with increasing soil depth from the surface to approximately 20 cm and decreased rapidly in the parent material. The unsaturated hydraulic conductivities of the same column plotted as a function of matric water potential are shown in Fig. 5. At matric water potential higher than approximately -40 cm of water, the unsaturated hydraulic conductivity decreased with increasing soil depth. The reverse is true at matric water potential below approximately -40 cm of water. The major advantage of using the undisturbed soil column containing several horizons for hydrologic characteristics measurements is that the saturated or the unsaturated hydraulic conductivities as functions of different depths may be obtained from a single determination.

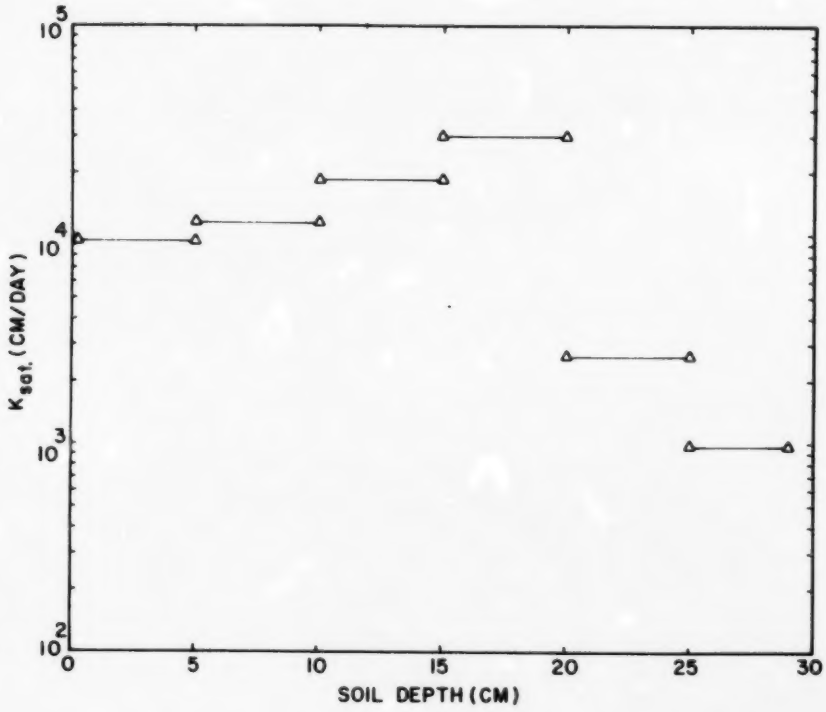

Fig. 4. Saturated hydraulic conductivity vs soil depth interval.

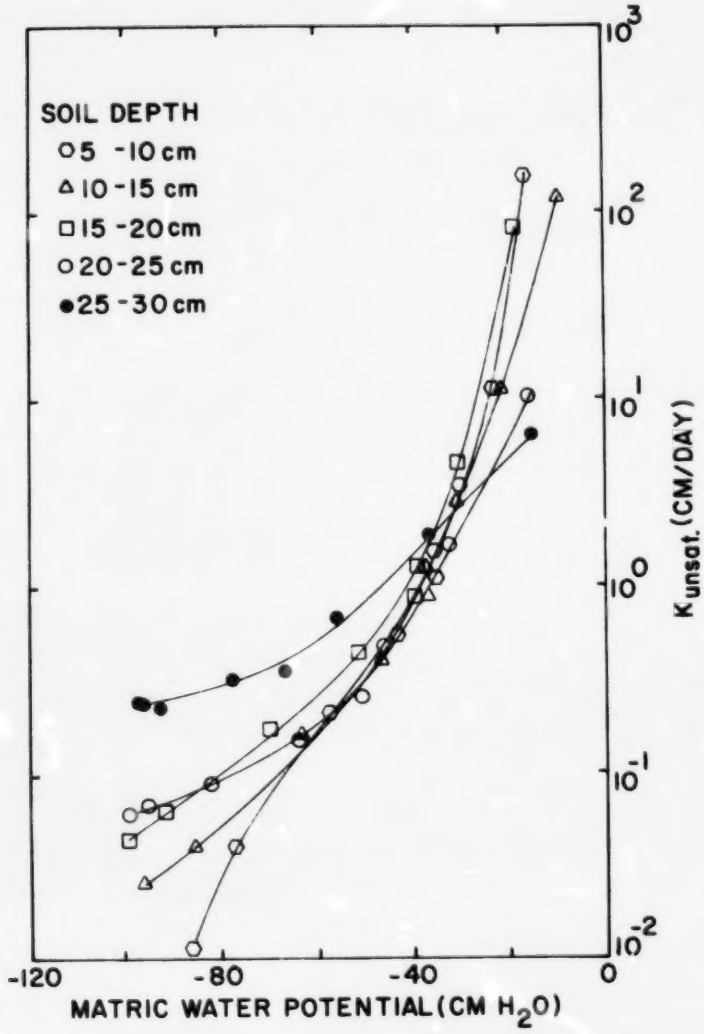

Fig. 5. Unsaturated hydraulic conductivity vs matric soil water potential for different soil depth intervals.

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